Year 11 Physics Term 1 Week 3

Measurement and Conversion

Recall That

- Units that are not built from other units are called base units.
- Some units are built up from other units.
- eg the unit of area is built from the unit of length.

Area = length x length

Square metre = metre x metre

$m^2 = m^1 \times m^1$

Derived unit

Base unit

- Units that are built up from other units are known as **derived** units.
- The square metre is a derived unit.
- Different units may be used to make up a derived unit eg $m\ s^{-1}$
- The different units are separated by a space.
- Sometimes one symbol represents two or more different base units.
- Eg: The unit for force is the newton.
- Its symbol is N.
- The newton is derived from the base units kilogram, metre and second:

$$\mathbf{N = kg\ m\ s^{-2}}$$

Base Units

Name	Symbol	Topic Area
metre	m	Length
second	s	Time
kelvin	K	Temperature
kilogram	kg	Mass
ampere	A	Electric current
mole	mol	Amount of substance
candela	cd	Luminous intensity

Derived Units

Name	Symbol	Topic Area
newton	N	Force
joule	J	Energy
hertz	Hz	Frequency
ohm	Ω	Electric resistance
volt	V	Potential difference
watt	W	Power
pascal	Pa	Pressure

- When a unit is used which has a power of 1, the power is excluded for convenience, eg
- m^1 = m
- s^1 = s

The Greeks

- Many of the topic areas are abbreviated using the Greek alphabet, eg

Name	Symbol	Topic Area
Theta	θ	Temperature
Lambda	λ	Wavelength
Mu	μ	Friction Coefficient
Rho	ρ	Density
Sigma	Σ	Stefan's Constant
Omega	Ω	Electrical Resistance

Operations with units

- **Addition and subtraction**
- Measurements can only be added or subtracted if they have the same units.
- **Multiplication**
- When multiplying the same topic area units the indices (power numbers) are added together.

$\mathbf{m^1 \times m^1 = m^2}$	ie: $m \times m = m^2$	eg $2\ m \times 2\ m = 4\ m^2$

- **Division**
- When the same units with the same power are divided they cancel each other and in some cases the result is a ratio.

$$\frac{\mathrm{m}}{\mathrm{m}} = \mathrm{ratio}\left(\mathrm{no\ units}\right) \qquad \text{eg} \qquad \frac{6\,\mathrm{m}}{2\,\mathrm{m}} = 3$$

- When different topic area units are divided, the denominator (bottom of the fraction) unit changes its power sign from positive to negative or vice versa.

$$\frac{\mathrm{m}}{\mathrm{s}} = \mathrm{m\,s^{-1}} \qquad \text{eg} \qquad \frac{8\,\mathrm{m}}{2\,\mathrm{s}} = 4\,\mathrm{m\,s^{-1}}$$

Submultiple units

- When using a 30 cm ruler to measure objects, most people take the measurement in centimetres or millimetres since it is easier to write 5 mm than 0.005 m.
- Base units that are too big for some measurements, for example, the metre can be split into
- smaller units, e.g. the millimetre.
- Base units can be split into smaller units called submultiple units.
- The millimetre is an example of a submultiple unit and it is a smaller quantity than the metre.
- **A submultiple unit is a smaller quantity unit than a base unit.**

Multiple units

- Sometimes the base unit can be too small. For example, large distances are often measured in kilometres instead of metres.
- The kilometre is a larger quantity than the metre.
- **A multiple unit is a larger quantity than the base unit.**

- Common prefixes used for multiple and submultiple units are shown in the table below:

Prefix	Symbol	Number in words	Number in figures	Powers of ten
Mega	M	Million	1 000 000	10^{6}
Kilo	k	Thousand	1 000	10^{3}
Centi	c	Hundredth	$\frac{1}{100}$	10^{-2}
Milli	m	Thousandth	$\frac{1}{1\,000}$	10^{-3}
Micro	u	Millionth	$\frac{1}{1\,000\,000}$	10^{-6}

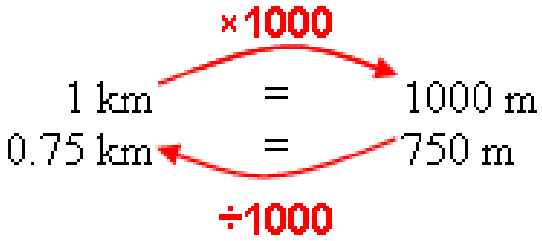
- Multiple and submultiple units **must** be converted into SI units when used in formulae for problem solving.

Conversion of units

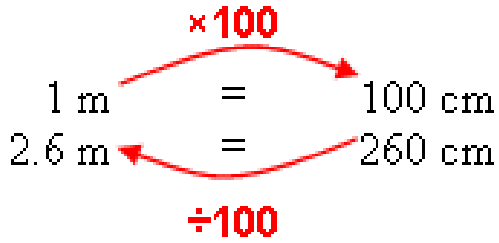
- Conversion is an operation of changing submultiple or multiple units into SI base units.
- The Conversion Factor is the figure, which relates the multiple, or submultiple unit to the SI unit.

Units of Length

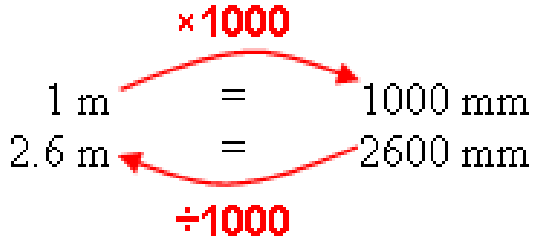
Kilometres and Metres



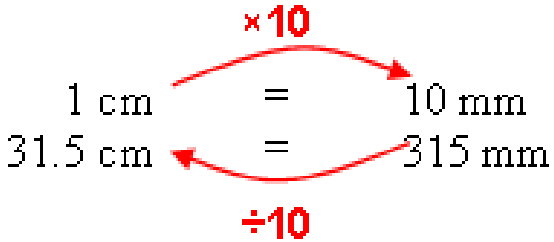
Metres and Centimetres



Metres and Millimetres

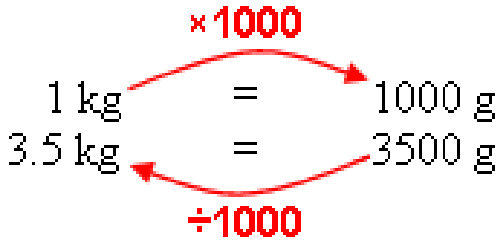


Centimetres and Millimetres

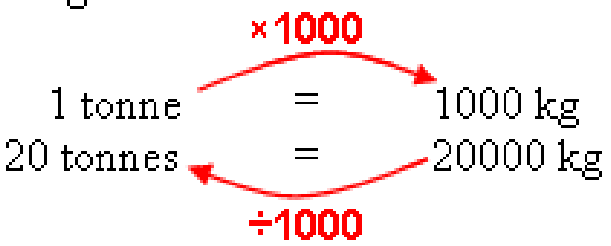


Units of Mass

Kilograms and Grams

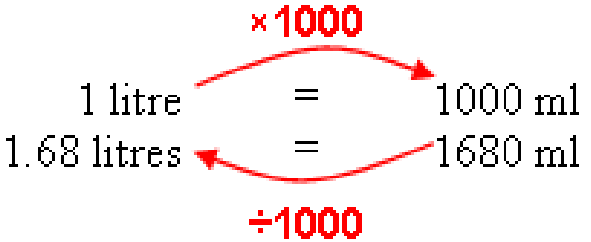


Tonnes and Kilograms



Units of Capacity

Litres and Millilitres



Rules for conversion

- **Rule 1**
- When converting a multiple unit (larger quantity) into the SI base unit (smaller quantity), multiply the **multiple unit** by the conversion factor.

Larger Quantity ------> Smaller Quantity = Multiply by a factor

Example 1

- The kilometre is a multiple unit of the SI base unit of length, the metre.
- A kilometre is one thousand times larger than the metre.

Multiple	Conversion Factor	Conversion	SI units
1 kilometre (km)	1 000	1 x 1 000	1 000 m

Relationship 1 kilometre = 1 000m = 1 x 10^3 m

- **Rule 2**
- When converting a submultiple unit (smaller quantity) into the SI base unit (larger quantity) **divide** the submultiple unit by the conversion factor.

Smaller Quantity--------> Larger Quantity = Divide by a factor

Example 2

- The millimetre is a submultiple unit (smaller quantity) of the SI base unit of length, the metre.
- A millimetre is one thousand times smaller than the metre.

Submultiple	Conversion Factor	Conversion	SI units
1 millimetre (mm)	1 000	1/1000	0.001 m

Relationship 1 millimetre = 0.001 m = 1 x 10^{-3} m

Conversion examples

Multiple or Submultiple	Conversion Factor	Relationship
Multiple – kilometre km	1 000	1 km = 1 000 m
Submultiple – centimetre cm	100	100 cm = 1 m
Submultiple – millimetre mm	1 000	1 000 mm = 1 m

5 kilometres

$5\ \text{km} = 5 \times 1\,000 = 5\,000\ \text{m} = 5 \times 10^{3}\ \text{m}$

25 centimetres

$25\ \text{cm} = \frac{25}{100} = 0.25\ \text{m} = 2.5 \times 10\ \text{m}^{-1}$

236 millimetres

$236\ \text{mm} = \frac{236}{1\,000} = 0.236\ \text{m} = 2.36 \times 10^{-1}\ \text{m}$

Volume

- Derived unit cubic metre (m^3)

Multiple or Submultiple	Conversion Factor	Relationship
Submultiple – cubic millimetre mm^3	1 000 000 000	1 000 000 000 mm^3 = 1 m^3
Submultiple – cubic centimetre cm^3	1 000 000	1 000 000 cm^3 = 1 m^3
Submultiple – cubic decimetre dm^3 (or litre l)	1 000	1 000 dm^3 = 1 m^3 (or litres)

Volume Examples

102 dm^3 or litres

$$102 \text{ litres} = \frac{102}{1\,000} = 0.102 \text{ m}^3 = 1.02 \times 10^{-1} \text{ m}^3$$

235 cubic centimetres

$$253 \text{ cm}^3 = \frac{235}{1\,000\,000} = 0.000235 \text{ m}^3 = 2.35 \times 10^{-4} \text{ m}^3$$

10290 cubic millimetres

$$10290 \text{ mm}^3 = \frac{10\,290}{1\,000\,000\,000} = 0.00001029 \text{ m}^3 = 1.029 \times 10^{-5} \text{ m}^3$$

Mass

SI unit kilogram (kg)

Multiple or submultiple	conversion factor	Relationship
Submultiple – gram g	1 000	1 000 g = 1 kg
Multiple – tonne t	1 000	1 tonne = 1 000 kg

Mass Examples

200 grams

$$200\ \text{g} = \frac{200}{1\,000} = 0.2\ \text{kg} = 2 \times 10^{-1}\ \text{kg}$$

3.3 tonne

$$3.3\ \text{tonne} = 3.3 \times 1\,000 = 3\,300\ \text{kg} = 3.3 \times 10^{3}\ \text{kg}$$

Time

SI unit second (s)

Multiple or submultiple	Conversion factor	Relationship
Multiple – minute min	60	1 min = 60 s
Multiple – hour h	3 600	1 h = 3 600 s

Time Examples

5 minutes

5 minutes = 5 x 60 = 300 s = 3.0×10^2 s

2 hours

2 hours = 2 x 3 600 = 7 200 s = 7.2×10^3 s

Density

Derived unit kilogram per cubic metre

$kg\ m^{-3}$

0.8 gram per cubic centimetre

$0.8\ g\ cm^{-3} = 0.8 \times 1000 = 800\ kg\ m^{-3} = 8.0 \times 10^{2}\ kg\ m^{-3}$

5.6 gram per cubic centimetre

$5.6\ g\ cm^{-3} = 5.6 \times 1000 = 5\,600\ kg\ m^{-3} = 5.6 \times 10^{3}\ kg\ m^{-3}$

Force

Derived unit newton (N)

Multiple or submultiple	Conversion factor	Relationship
Multiple kilonewton kN	1 000	1 kN = 1 000 N

5 kilonewtons

5 kN = 5 x 1 000 = 5 000 N = 5.0×10^3 N

8.26 kilonewtons

8.26 x 1 000 = 8 260 N = 8.26×10^3 N

Converting km/h to m/s

- If you have two units at a time, you use two conversion factors.
- eg, to convert 50 km/h to m/s you convert km to m and 1/ h to 1/ s:

$$50\ \frac{\text{km}}{\text{h}} \times \frac{1000\ \text{m}}{\text{km}} \times \frac{1\ \text{h}}{3600\ \text{s}} = 13.9\ \frac{\text{m}}{\text{s}}$$

- Converting three units at a time, requires you use three conversion factors.
- eg to convert 50 mph to m/s you convert mph to km, km to m and 1/ h to 1/ s: